FL-MFCS

Microfluidics Control System

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INSTRUCTION MANUAL

Serial No._____

011211

World Precision Instruments

MicroFluidics Control System

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ABOUT THIS MANUAL

The following symbols are used in this guide:

This symbol indicates a **CAUTION**. Cautions warn against actions that can cause damage to equipment. Please read these carefully.

This symbol indicates a **WARNING**. Warnings alert you to actions that can cause personal injury or pose a physical threat. Please read these carefully.

NOTES and **TIPS** contain helpful information.

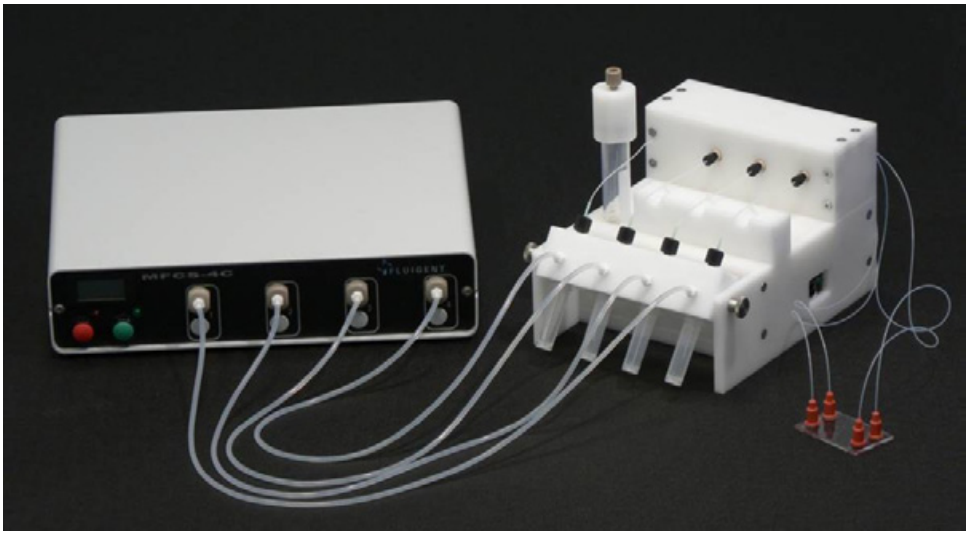


Fig. 1—FIowell microfluidics system

INTRODUCTION

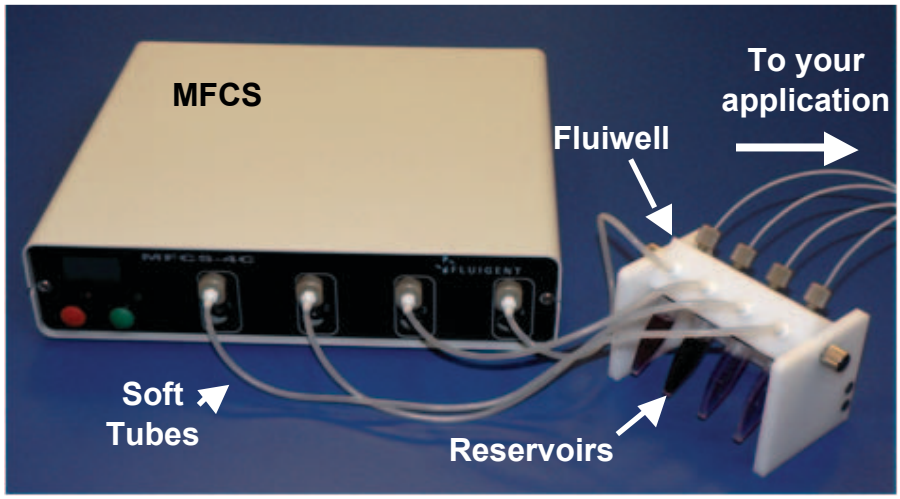


Fig. 2—Connecting the MFCS system

The MicroFluidic Control System (MFCS) is a high-precision, pneumatic pressure controller designed to handle fluid in microfluidics systems (microchannels and nanochannels, capillaries, Lab-on-chips…).

It allows a stable and pulsation free flow with short response times (100ms) and a stabilization time as low as 1s. With the MFCS it is also possible to control several independent channels (up to 16 cf Labiview VI) simultaneously. The user friendly software allows you to create scripts for complex flow patterns or dynamic coupling for user-controlled dependence between channels.

Channels	**Pressure Range (mBar)**					
	0–25	**0–69**	**0–345**	**0–1000**	**-25–0**	**-69–0**
4 Channel	MFCS-4C-25	MFCS-4C-70	MFCS-4C-345	MFCS-4C-1000	MFCS-NEG-4C-25	MFCS-NEG-4C-70
8 Channel	MFCS-8C-25	MFCS-8C-70	MFCS-8C-345	MFCS-8C-1000	MFCS-NEG-8C-25	MFCS-NEG-8C-70
Pressure type	P>0				P<0	

Parts List

After unpacking, verify that there is no visible damage to the instrument. Verify that all items are included:

(1) MFCS unit

(1) power supply and a power line cable

(1) USB cable

(1) pneumatic connection kit (4 soft tube adapters, 4x50cm of soft tube (OD 3mm ID 1mm), a ¼" wrench) For a 8 channel MFCS, 8 adapters are included.

(1) Instruction Manual

Fig. 3—Parts of the MFCS system

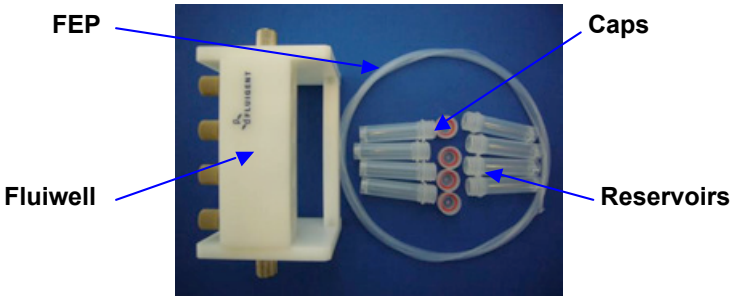


Fig. 4—Optional accessories for the MFCS system include a Fluiwell and a set of spare parts.

Unpacking

Upon receipt of this instrument, make a thorough inspection of the contents and check for possible damage. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed damage should be reported at once to the carrier and an inspection requested. Please read the section entitled "Claims and Returns" on page 40 of this manual. Please contact WPI Customer Service if any parts are missing at 941.371.1003 or customerservice@wpiinc.com.

Returns: Do not return any goods to WPI without obtaining prior approval (RMA # required) and instructions from WPI's Returns Department. Goods returned (unauthorized) by collect freight may be refused. If a return shipment is necessary, use the original container, if possible. If the original container is not available, use a suitable substitute that is rigid and of adequate size. Wrap the instrument in paper or plastic surrounded with at least 100mm (four inches) of shock absorbing material. For further details, please read the section entitled "Claims and Returns" on page 40 of this manual.

INSTRUMENT DESCRIPTION

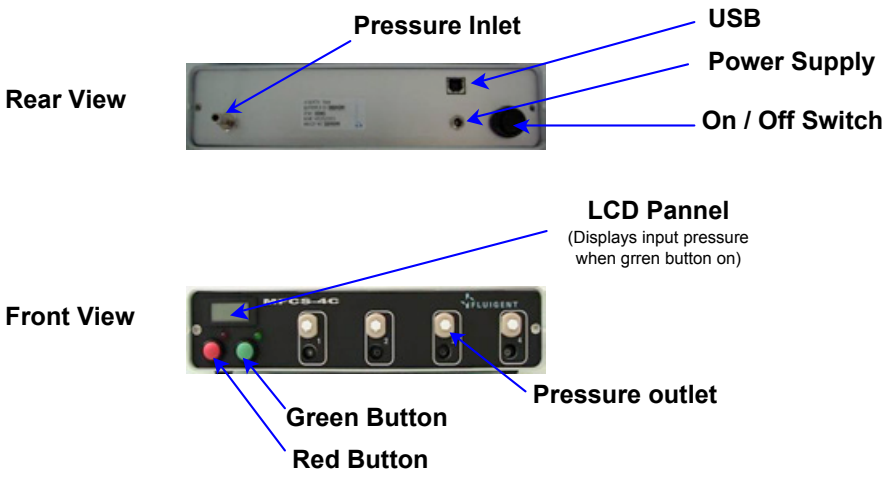


Fig. 5—MFCS front and rear panels are labeled.

Required Materials

The MFCS requires the following materials:

- A computer:
  - USB 1.1 port or faster
  - Screen resolution of 1024x768
  - Intel Pentium II 500 MHz or faster
  - Windows 2000, Windows XP
  - 5Mb of free disk space
- A pneumatic pressure source:
  - Dry, non-corrosive (use an air drier)
  - Dust and oil-free
  - Pressure regulator to tune the input pressure value
  - 0.01µm Filter
  - Pressure range of the pump to suit your MFCS input pressure (Fig. 6)

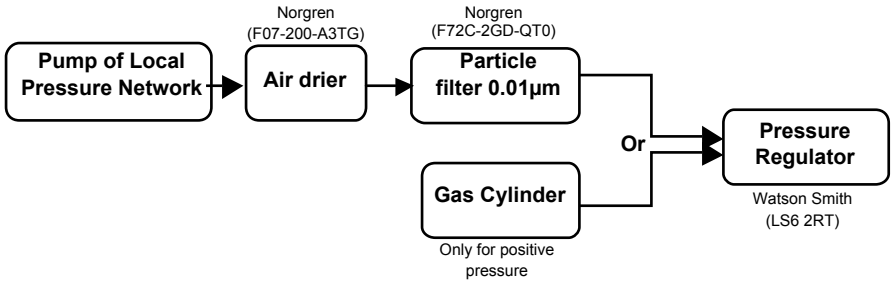


Fig. 6—Suggested pressure source scheme

Pressure Range	mBar	0 to 25	0 to 69	0 to 345	0 to 1000	−25 to 0	−69 to 0
	PSI	0.35	1.00	5.00	14.50	−0.35	−1.00
Input Pressure value	mBar	500	500	800	1300	− 500	− 500
	PSI	7.25	7.25	11.60	18.86	−7.25	−7.25

Fig. 7—Input pressure value according to the MFCS pressure range

Connection to the MFCS requires either:

- The Fluiwell, a microfluidic interface between the MFCS and your Microdevice that uses 1/16″ OD tube or smaller (see Fig. 8)
- Your own connection system

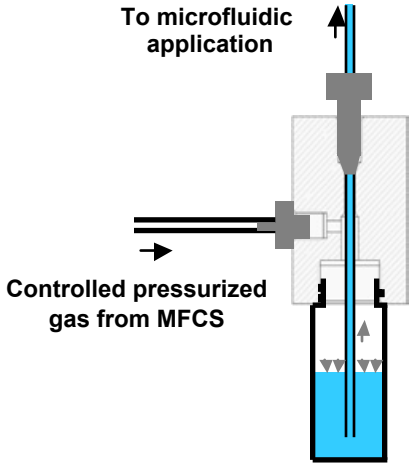


Fig. 8—Fluiwell's working principle

Setup

WARNING: MFCS MUST BE USED IN A CLEAN AND DRY ENVIRONMENT.

WARNING: NO LIQUID SHOULD ENTER THE DEVICE. THIS VOIDS THE WARRANTY.

WARNING: THE PRESSURE SOURCE MUST BE DRY, DUST AND OIL FREE. USE A 0.01μm FILTER AND A PRESSURE REGULATOR TO INSURE PROPER INPUT PRESSURE.

Fig. 9—Setting up the MFCS with Fluiwell

Please follow the next series of operation in order to set properly your MFCS.

1. Unpack the MFCS.

   NOTE: If something is damaged, email TechnicalSupport@wpiinc.com.

Fig. 10—MFCS unit

2. Make the following connections on the rear panel:
   - USB cable
   - Power supply
   - Pressure source

   RUN CLEAN, DRY GAS THROUGH A PRESSURE REGULATOR BEFORE CONNECTING THE PRESSURE SOURCE TO THE MFCS. (See "Required Materials" on page 5)

Fig. 11—Connections made to the back panel

3. Insert the MFCS software CD into the computer. Copy the folder corresponding to

your device (MFCS-4C for 4 channels and MFCS-8C for 8 channels) folder to desired location on your hard drive.

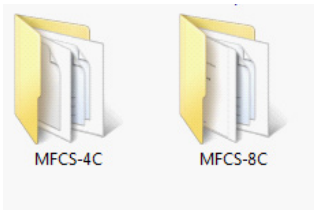


Fig. 12—Folder icons shown on the CD

4. Open the folder you just copied on your hard drive. Then double click on the software folder that has the same name.

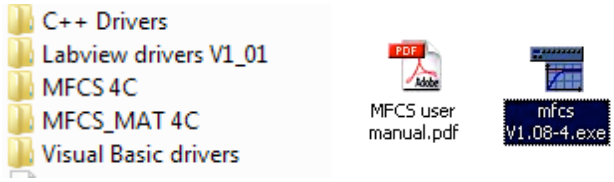


Fig. 13—Double click on the MFCS4C to install the MFCS4.

5. Turn the MFCS ON using the switch on the rear panel. The red light illuminates to indicate that the power is on. If not, check the power supply and the USB cable.

Fig. 14—The red LED illuminates to indicate the power is on.

6. Double click on the MFCS control icon.

Fig. 15—The MFCS icon is highlighted in the image.

7. The software opens and is ready for use.

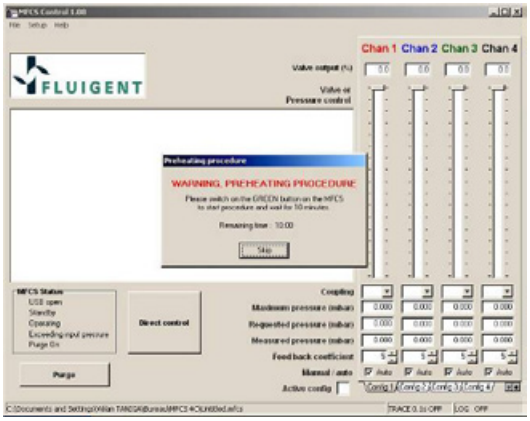


Fig. 16—MFCS software welcome screen

8. The pressure source must be CLEAN AND DRY and fixed to the input pressure value specified on the rear panel of your MFCS. It is located next to the input pressure valve of the MFCS.

Fig. 17—The label indicates the correct input pressure for your system.

Pressure Range (mBar)	25	69	345	1000	–25	–69
Input Pressure value (mBar)	500	500	800	1300	–500	–500

9. Press the green button and set the pressure source to the input pressure value of your MFCS. The preheating will start. A preheating procedure is necessary to warm up the MFCS (10 min.). Meanwhile, you can continue with the next step. Avoiding this step can decrease the pressure control stability and accuracy. Preheating is only necessary once a day.

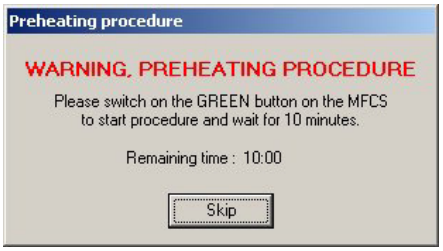


Fig. 18— When the green button is pressed, the green LED illuminates (left) and the warning appears on the computer screen (right).

10. Unpack the Fluiwell (optional accessory, not included). Verify that the four toric seals

are in place, before mounting the reservoirs.

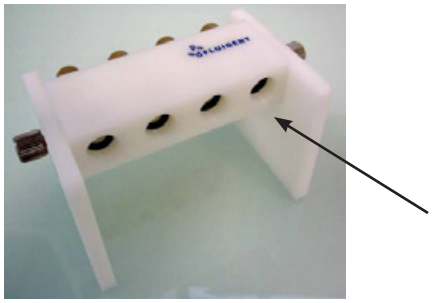


Fig. 19—A toric seal is marked by the arrow in the image.

11. Screw the 2mL reservoirs on the Fluiwell.

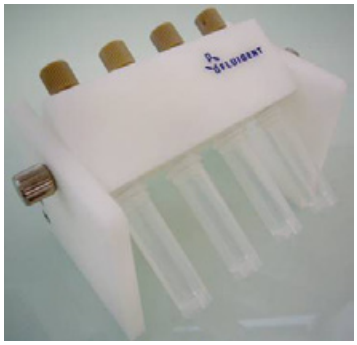


Fig. 20—The reservoirs are in position.

12. Prepare your experimental setup by gathering all the devices and elements you might need. The length of the tubing corresponds with the distance between the Fluiwell and the MFCS.

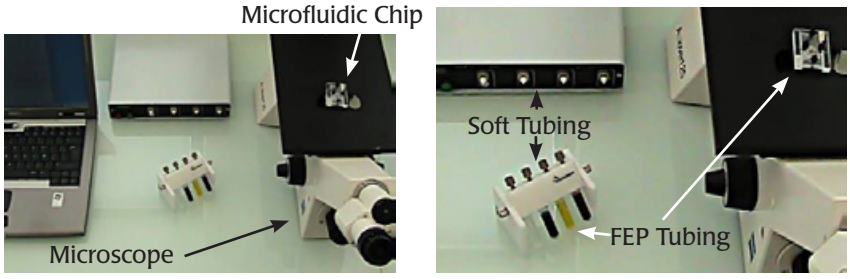


Fig. 21—Position the system components as shown in the image.

13. The connectors that are included with the system are 0.0625". If you prefer to use

different connectors, see Appendix A for a list of suppliers. You can also find suppliers for the tubing in the appendix. You will need four pieces of soft tubing and four pies of FEP tubing. (For the MFCS-8C, you will need eight pieces of each.)

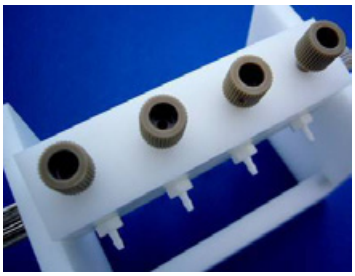


Fig. 22—The included connectors are installed (left). The image (right) shows the soft tubing on the top and the FEP tubing on the bottom.

14. Connect the soft tubing to the Fluiwell.

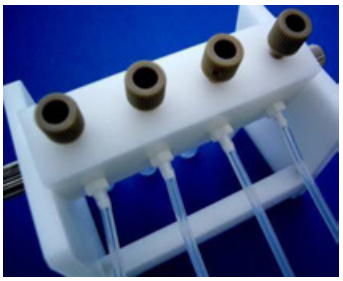


Fig. 23—The soft tubing is connected.

15. Connect the FEP tubing to the top outlets. Screw the fitting down finger tight in order to avoid leaks. The FEP tubing should be visible inside the 2mL reservoirs.

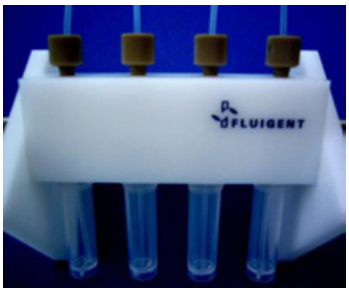


Fig. 24—The FEP tubing extends into the 2mL reservoirs.

16. Your Fluiwell is ready to connect with your microfluidic chip and the MFCS. Before making the connections, fill the 2mL reservoirs with your sample.

Starting the MFCS

1. Remove the protection caps from the MFCS outlets. Use the provided wrench or any ¼" tool.

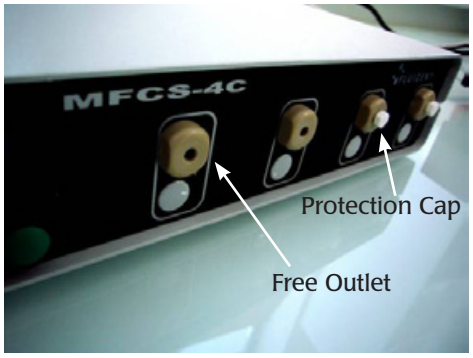


Fig. 25—Remove the caps from the outlets.

2. Tightly screw the soft tube adapters on the outlets

Fig. 26—Soft tube adapter are screwed into the outlets.

3. Connect the soft tubing to the MFCS outlets.

Fig. 27—The soft tubing from the Fluiwell is connected to the soft tube adapters on the MFCS outlets.

4. Connect the Fluiwell to your microfluidic chip, using the FEP tubes. A list of adapters for smaller inner diameters tubes is available in the appendix.

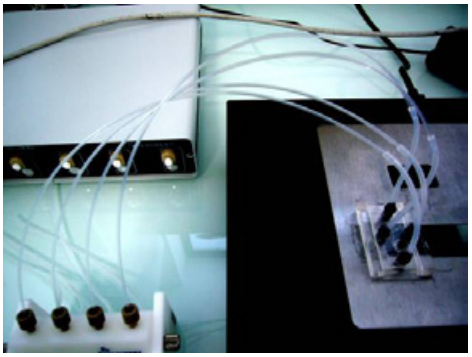


Fig. 28—Connect the Fluiwell to the microfluidic chip.

5. Fill the 2mL reservoirs with the appropriate fluid corresponding to the inlets of your chip.

6. At the end of the preheating countdown:
   - Push the red button
   - On the computer interface, calibrate the MFCS by selecting Setup>Compensate offset. Click the Save to MFCS button to load your calibration parameters into the MFCS and close the window.

   In order to guarantee the accuracy of your measurements, we recommend calibrating the device every time you move it. Otherwise, once a month is sufficient.

   The MFCS is ready to be used.

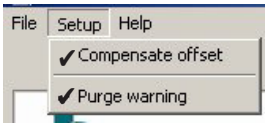


Fig. 29—MFCS Setup menu

Fig. 30—Offset Compensation Window

Fig. 31—Save to MFCS button

OPERATING INSTRUCTIONS

Here you will learn how to operate the MFCS using the MFCS control interface.

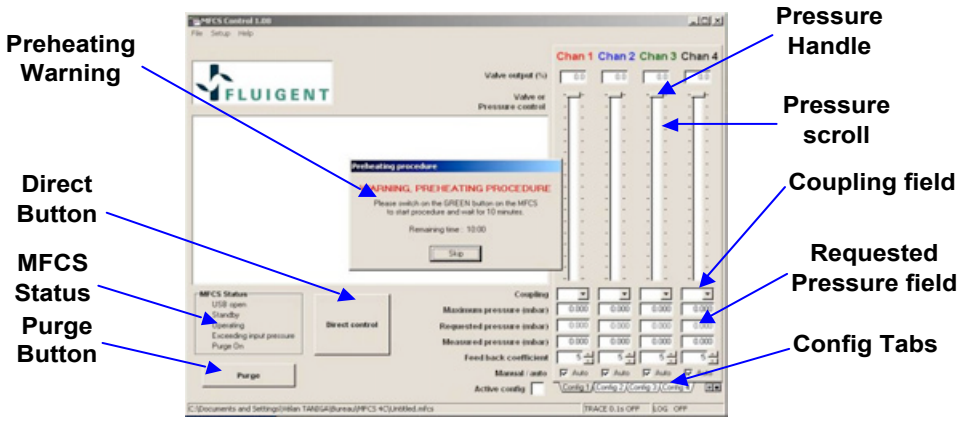


Fig. 32—MFCS software control interface

Purging

1. Click on the Purge button. A warning appears asking for confirmation. Click Yes.

Fig. 33—Warning message

NOTE: A purge feature is available in channel 1. It applies maximum pressure on this channel. It suits any filling or emptying purpose.

2. To disable the purge, click the Purge button again. The Purge On (green) indicator appears until you stop the purge.

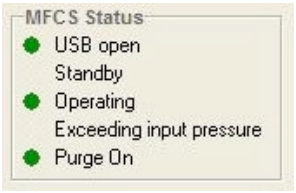


Fig. 34—SFCS Status window

Controlling Pressure in the Channels

There are two different way to modify the pressure in a channel:

1. Press the Direct Control button to activate the control of the MFCS. Otherwise, the orders will not be transmitted.
2. Then, choose one of the following options.
   - Change the pressure in the channels, using the corresponding handle.

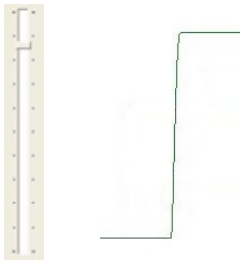


Fig. 35—Move the slider up to raise the pressure.

   - Enter the numerical value of the pressure in the requested pressure field.

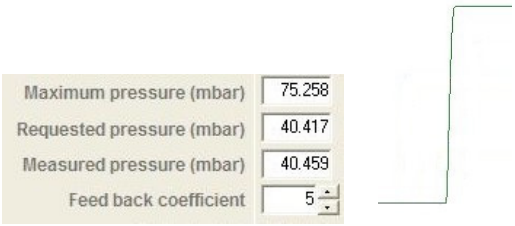


Fig. 36—Enter the desired pressure into the appropriate field to change pressure in the channels.

Keyboard Shortcuts:

- Up arrow: Moves the handle up one step
- Down arrow: Moves the handle down one step
- Page up: Moves the handle up 10 steps
- Page down: Moves the handle down 10 steps
- Home: Moves the handle to the top of the scale
- End: Moves the handle to the bottom of the scale

Tab Configurations

1. You can use the config tabs to set different handle patterns in order to easily switch between several pressure sets by clicking on the corresponding tab.

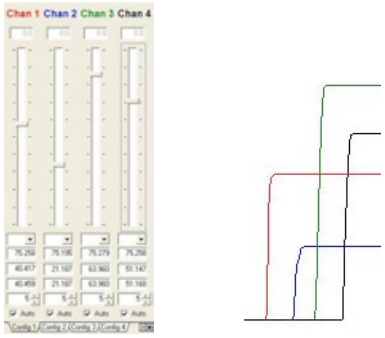


Fig. 37—Use the configuration tabs along the bottom of the window to switch between several pressure sets. An example is shown in the graph above.

2. The curves will follow the pressure pattern. (See "MFCS Mat (Scripting Software)" on page 19 or "Labview" on page 21 for automated pattern setting).

Fig. 38—This sample shows a pressure pattern with no curve.

Saving Curves

1. To save a set of curves, first choose the desired trace (sampling) rate.

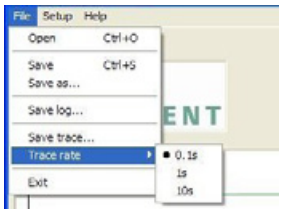


Fig. 39—Choose File>Trace rate to select the desired sampling rate.

2. Choose File>Save Trace to start recording. Give a name to the curves file in Save Trace dialog box of the file menu. (A check mark appears next to the Save trace menu item.)

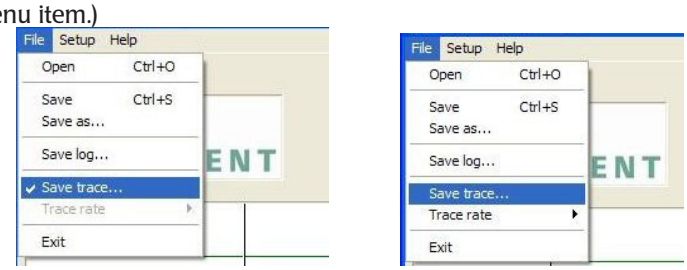


Fig. 40—File menu with a check mark next to the Save Trace option indicates the system is recording, and the menu without a check mark shows the system is not recording.

3. To end the recording, choose File Save Trace again. (The check mark disappears.) The trace file is saved as a text file that can be imported into any spreadsheet. The file looks similar to the example shown below.

03/09/2020	08 15:2	1:39 MFCS	Automat V:	1.05 MFCS	S/N:0005 V:000B
15:21:39	11463	174,942	140,017	0	0,105
15:21:39	11464	175,258	140,017	0	0,105
15:21:39	11465	174,942	140,017	0	0,105
03/09/2020	08 15:2	2:05 --EN	D OF TRACE-	-	

Fig. 41—The table shows the time of the experiment, the time step nº, pressure of channel 1, pressure of channel 2, pressure of channel 3 and pressure of channel 4. In addition it has a line to indicate the start and one for the finish.

For more information on curve file formats, see "Trace and Log Flle Formats" on page 38.

Coupling

Coupling is a feature that creates software driven dependence between channels. Thus, it is possible to increase pressure in one channel while the pressure in a second one is decreasing with the same variation. Both parallel and anti-parallel coupling are possible.

- To set a parallel coupling between channel 1 and channel 2, choose A + for both channels in the coupling field.
- To achieve an anti-parallel coupling, just choose A- for one of the two channels.
- To couple more than one channel, set the coupling field of each channel.

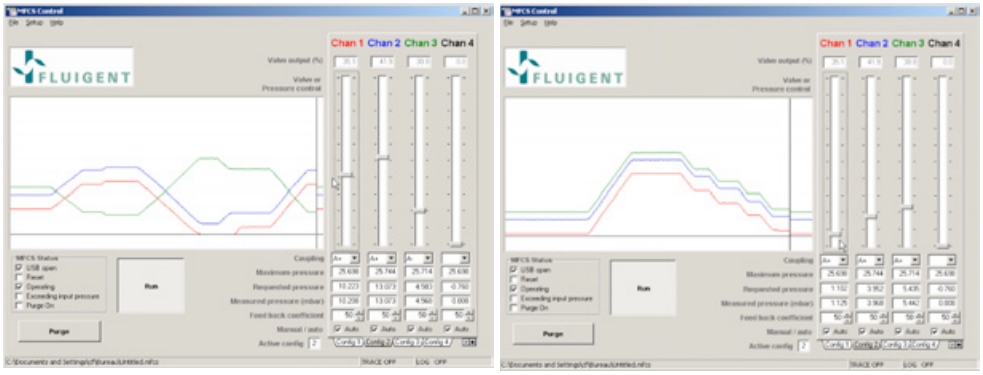


Fig. 42—Anti-parallel coupling allows changes in the pressure difference of two channels without changing the pressure sum. Parallel coupling keeps the pressure difference constant.

Keyboard Shortcut:

It is possible to temporally disable the coupling feature of a set of channels by pressing the shift key. Then, move the handles independently.

Manual/Auto Modes

The manual mode provides a proportional control on the valves. The handles directly control the valves opening, and no regulation occurs. This mode is only adapted for special use and it is subject to intrinsic nonlinear characteristics, hysteresis and limited reproducibility of the solenoid-valves.

The auto mode provides a direct control on the pressure inside the channels. The handles set the requested pressure and the embedded regulation program computes the command to give to the valves in order to have a stable, quick and reproducible response.

Feedback Coefficient

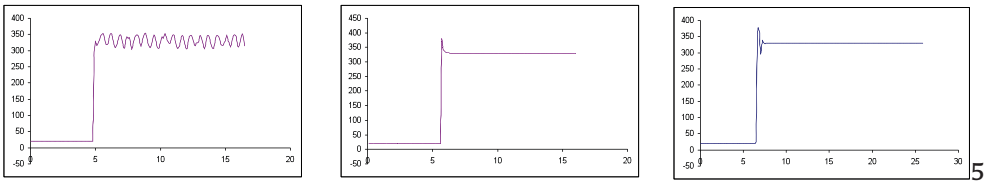


Fig. 43—In the first graph, the feedback coefficient is too high. In the second, it is optimized. In the third, it is too low. These graphs show the effect of the feed back coefficient value on the pressure stability and response time.

The MFCS Control software provides optimal pressure and flow regulation for a wide range of microfluidic applications, in particular those involving extremely low pressures and or volume flow rates (µL to pL/min). However, when using large volumes, an

adjustment of the feed-back loop's reactivity can be necessary to achieve optimal results. This can be achieved independently for each channel by adjusting the feed back coefficient.

The factory setting is 5, a smaller coefficient results in a slower reaction, a higher value gives a faster response.

If the feedback coefficient is too high, the regulation loop can become unstable and pressure control inside the channel is no longer possible. The optimal response is obtained just below the critical damping situation between a monotonous return to equilibrium and oscillatory overshooting (See Fig. 43).

NOTE: For high pressure versions of the MFCS, at the initial factory setting, operation is oscillation-free for small pressure changes but shows overshooting and transient oscillations for drastic pressure changes. If this overshooting is a nuisance to your application, it can be suppressed by decreasing the feedback coefficient. You will lose some of the regulation speed for small pressure changes. A working balance must be achieved. The optimal value depends on several features of the connected system, including: volume and elasticity of tubing, hydrodynamic resistance and geometry of the microfluidic channels and the time constant of the phenomena under investigation.

MFCS Mat (Scripting Software)

General Description

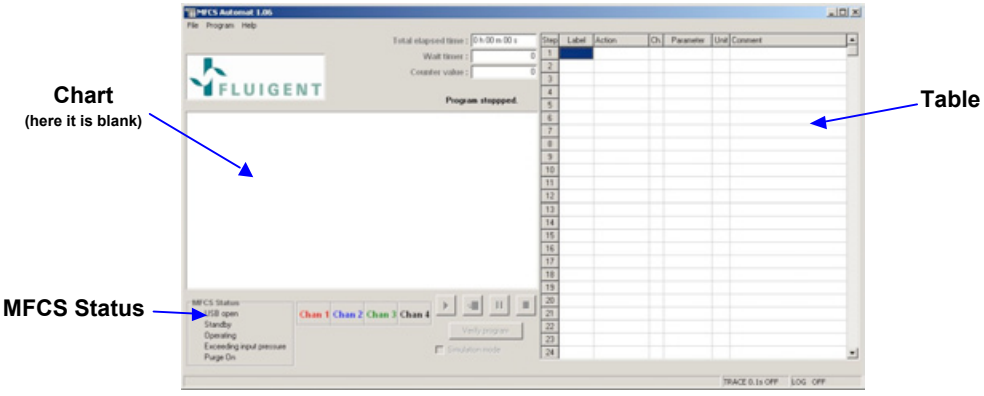


Fig. 44—MFCS Automat window

MFCS mat is a script software that allows you to create automated pattern of pressure.

In the main window (Fig. 44), you can find:

- A chart showing the pressure value of all the channels (here it is blank),
- Below the chart, the MFCS status is shown with the following buttons: Play, Pause, Stop and Verify program.
- On the right hand side, you can add different actions in the table (script).

Description of the Table

In this table, there are six columns:

- Label needs a string. It is where the action « Goto label » looks for.
- Action: define the type of action
- Ch: define the channel number where the action is applied.
- Parameter: define the parameter of the action if necessary,
- Unit: specify the unit of the parameter (automatically set)
- Comment: define a comment of the current action.

Descriptions of the Actions

Actions	Parameters	Description
Alpha	Integer from 0 to 255 (n)	This value is linked to the feedback coefficient for the pressure regulation. (default value 5)
Auto	Double (x)	Send a pressure order in mBar to the specified channel
End		End programme
Goto label	String (s)	Go to the line with the s string in the labeled column
Manual	Double (x)	The channel is control manually without feedback control. X is equivalent to the % of aperture of the Electrovalve.
Purge off		Stop purge on channel 1
Purge on		Start purge on channel 1
Wait	Double (x)	The program waits for x secondes.

Script Example

Here is an example of a script with the corresponding pressure chart.

Step	Label	Action	Channel	Parameter	Unit
1		alpha	1	5	
2		alpha	2	5	
3	start	auto	1	175	mb
4		wait		20	s
5		auto	1	210	mb
6		auto	2	175	mb
7		wait	2	20	s
8		auto	2	140	mb
9		goto label		start	

This is an endless loop generating a 40 seconds period square pressure signal.

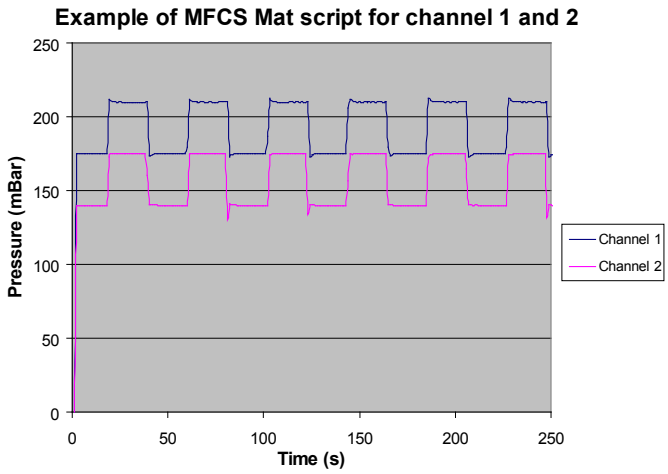


Fig. 45—The script above generates this output.

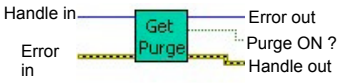
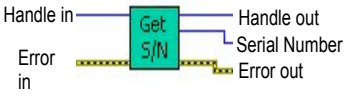
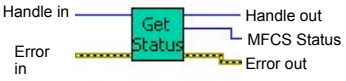
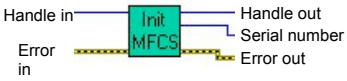
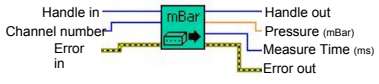
Labview

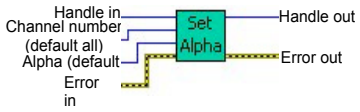
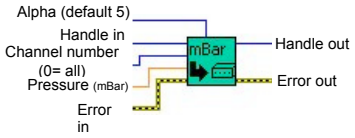
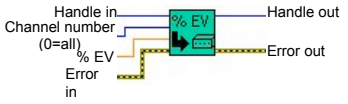
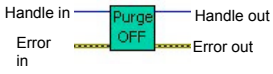
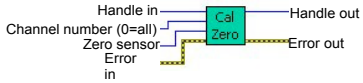
The Labview drivers are in the provided CD.

The Labview library provided is embedded with a set of functions that allows you to control the MFCS in your own Labview program. Here are a few examples of what you can achieve with this library.

Labivew VI

Labview VI	Symbol	Description
mfcs_close.vi	Handle, Error in, Close MFCS, Error out	Close the MFCS device and the allocated memory.
mfcs_data_chan.vi	Handle in, Channel data, Error in, Get Data, Handle out, Channel data, Error out	Get the characteristics of the specified channel: • Pressure unity (0=no sensor, 1=water inch, 2=PSI) • Maximum pressure range (in the specified unity) • Zero pressure value of the sensor (unsigned 12 bits) • Pressure value (unsigned 12 bits)

Labview VI	Symbol	Description
mfcs_get_purge.vi		Get status of the purge in channel 1: • True= Purge ON • False= Purge OFF
mfcs_get_serial.vi		Get the serial number of the MFCS (0 if no MFCS connected)
mfcs_get_status.vi		Get the status of the MFCS: • 0= MFCS is reset. MFCS needs to be manually rearmed (switch on GREEN button) • 1= Normal • 2= Pressure Supply Overpressure • 3= MFCS needs to be manually rearmed alter overpressure (switch on GREEN button)
mfcs_initialisation.vi		Initialize the MFCS device: • If the serial number is not specified or equal to 0, the first MFCS device found will be initialized. • If the serial number is specified, the corresponding MFCS device is initialized. Each MFCS has a unique serial number written on the back panel. • The VI returns the handle and the serial number of the MFCS (0 if no MFCS found).
mfcs_read_chan.vi		Get the pressure value (mBar) and the measure time (ms) of the specified channel (from 1 to 4 or 8).

Labview VI	Symbol	Description
mfcs_set_ alpha.vi		Set the alpha value (default =5) for the specified channel (from 1 to 4 or 8): • If the specified channel is 0, the same is applied to all channels. • Alpha is linked to the proportional value of the PID pressure regulation.
mfcs_set_ auto.vi		Set the regulated pressure value (mBar) for the specified channel (from 1 to 4 or 8): • If the specified channel number is 0, the same pressure is applied to all the channels. • It is also possible to set the alpha value
mfcs_set_ manual.vi		Set the electrovalve aperture (%) for the specified channel (from 1 to 4 or 8): • If the specified channel is 0, the same is applied to all channels. • The manual control of the electrovalve is not recommended and the output pressure is no longer regulated
mfcs_set_ purge_off.vi		Disable purge feature. Channel 1 can be used normally.
mfcs_set_ purge_on.vi		Enable purge feature. Channel 1 is directly connected to the pressure supply. Please use with care in order to avoid any damage to your microsystem.
mfcs_set_ zero.vi		Calibrate the zero pressure value of the specified channel. This value can be estimated with mfcs_data_ chan.vi.

Labview Examples

MFCS 8C control

Fig. 46—This VI is a transposition of MFCS control. It integrates MFCS control software's functions in a Labview environment:

1. Enter the serial number.
2. Calibrate the MFCS, if needed.
3. Set Pressure Order and Alpha (feedback coefficient) in the channels of interests.
4. Press Purge (channel 1 only) to fill or empty your device.
5. Press Stop to stop the pressure.

Control 2 MFCS

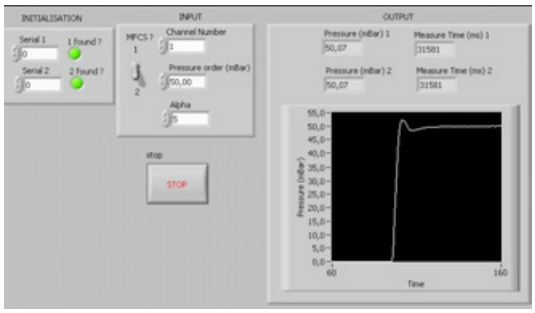


Fig. 47—This VI lets you control several MFCS at the same time.

1. Enter the two serial numbers.
2. Select the MFCS of interest with the 1/2 switch of the INPUT box.
3. Set the Channel number, Pressure order and appropriate Alpha (feedback coefficient).

4. Press the Stop button to stop pressure.

Calibration

The Calibration process can also be in operated from Labview interface

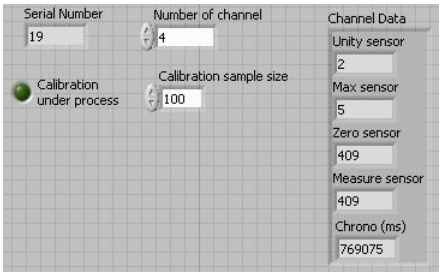


Fig. 48—Calibration controls

Set Pressure and Alpha–Analog Display

This example allows you to set an order (pressure and feedback coefficient) and then to read the result on an analog curve.

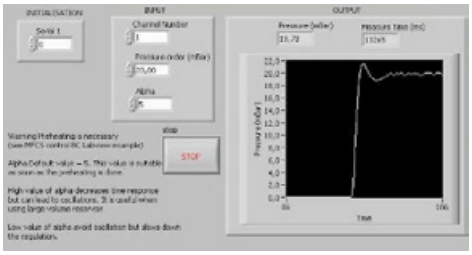


Fig. 49—Set the pressure and feedback coefficients.

Set Pressure–Digital Readout

This example allows you to set a pressure order and monitor the result on a numerical display.

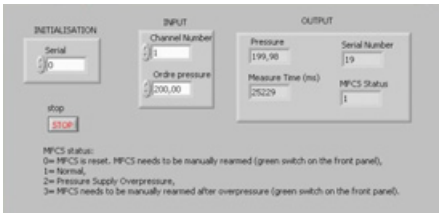


Fig. 50—Set the pressure and watch the numeric output.

C++ and VBA

Function Description (preliminary)

Here is a global description of the functions provided with the library.

mfcs_initialisation	Initialize the USB for the MFCS. If the serial number is not specified or equal to 0, the first MFCS device found will be initialized. If the serial Number is specified, the MFCS device with the designated serial number is initialized. Each MFCS has a unique serial number inscribed on the back panel. The vi returns the handle and a boolean that confirms that the USB initialized correctly.
mfcs_close	Close the MFCS device and the allocated the memory.
mfcs_set_purge_on	Connect the channel 1 output directly to the pressure supply. This function should be used with care, as it can cause damage to the microsystems connected.
mfcs_set_purge_off	Disconnect the channel 1 output from the pressure supply. Channel 1 can be used normally.
mfcs_get_purge	Get the status of the purge: • TRUE = purge ON, • FALSE = purge OFF
mfcs_get_status	Get the status of the MFCS: • -1= Trouble in the MFCS connections (USB or electric aperature) • 0= MFCS is reset. MFCS needs to be manually rearmed (green switch on the front panel) • 1= Normal • 2= Pressure Supply Overpressure • 3= MFCS needs to be manually rearmed after overpressure (green switch on the front panel)
mfcs_read_chan	Get the pressure value (mBar) and the measure time (ms) of the specified channel (from 1 to 4 or 8).
mfcs_data_chan	Get the characteristics of the specified channel: • Pressure Units (0= no captor, 1= inches of water, 2= PSI) • Maximum Pressure range (in the specified units) • Zero pressure value of the captor (unsigned 12 bits) • Pressure value (unsigned 12 bits) • Chrono value (unsigned 16 bits)
mfcs_get_serial	Get the Serial Number of the MFCS.

mfcs_set_auto	Set the regulated pressure (mBar) for the specified channel (from 1 to 4 or 8). If the specified channel is 0, the same is applied to all channels.
mfcs_set_alpha	Set the alpha value (default value =5) for the specified channel (from 1 to 4 or 8). If the specified channel is 0, the same is applied to all channels. Alpha is linked to the proportional value of the PID.
mfcs_set_manual	Set the electrovalve aperature (%) for the specified channel (from 1 to 4 or 8). If the specified channel is 0, the same is applied to all channels. The manual control of the electrovalve is not recommended and the output pressure is no longer regulated.
mfcs_set_zero	Save in the EEPROM the zero pressure value of the specified channel.

The following array gives an algorithmic description of the previous functions.

function	**return**	**parameter**	**Comment**
mfcs_ initialisation	UL handle	US serial number	Initialise USB connection and look for a MFCS with the specified serial number. handle = 0 if no USB connection
mfcs_close	B OK	UL handle	Close USB connection
mfcs_read	C error	UL handle	Read string on the interface
		S string	
mfcs_write	C error	UL handle	Write string on the interface
		S string	
mfcs_set_purge_ on	C error	UL handle	Open purge on channel 1
mfcs_set_purge_ off	C error	UL handle	Close purge on channel 1
mfcs_get_purge	C error	UL handle	Get the purge state
		PB purge state	
mfcs_get_status	C error	UL handle	Get MFCS status: 0 if the MFCS is reset 1 if normal 2 if overpressure 3 if MFCS needs to be rearmed.
		PC Status	

function	return	parameter	Comment
mfcs_read_chan	C error	UL handle	Read the pressure value (mBar) of the specified channel with the timing (time unit 25ms).
		C channel	
		PF pressure	
		PUS chrono	
mfcs_data_chan	C error	UL handle	Read the sensor data: - sensor unit: 0 = no sensor 1 = "H_2O (2.4908 mBar) 2 = psi (68.946 mBar) - full scale in pressure unit - zero value sensor (U12) - direct pressure measure (U12) - chrono (time unit 25ms)
		C channel	
		PC sensor unit	
		PUS sensor max	
		PUS zero	
		PUS measure	
		PUS chrono	
mfcs_get_serial	C error	UL handle	Get the serial number of the MFCS
		PUS Serial	
mfcs_set_auto	C error	US handle	Regulate pressure (mBar) on the specified channel. (if 0, the same for all channel)
		C channel	
		F pressure	
mfcs_set_alpha	C error	UL handle	Set the alpha value (U8). This value is linked to the PID performance. The recommended value is 50 for MFCS devices sold with MFCS_Control V1.05. For a more recent version (V1.06 and V1.07), the default value is 5 and a preheating of the electro-valves is necessary (45% aperature for 10 min).
		C channel	
		C alpha	
mfcs_set_manual	C error	UL handle	Set electro-valve voltage (%) on the specified channel. (If the value is 0, it is set the same for all channels.)
		C channel	
		F EV	
mfcs_set_zero	C error	UL handle	Save Zero sensor value on the firmware. To get this value, use mfcs_data_chan (PUS mesure)
		C channel	
		US Zero	

Definition of [C error]:

- - 0 = OK
- - 1 = USB closed
- - 2 = Wrong channel

symbol	bits	C++	Labview	VBA
UL	32	unsigned long	(U32)	ByVal Long
US	16	unsigned short	(U16)	ByVal Integer
PUS	32	pointer on unsigned short	(U16) by address	ByRef Integer
S	32	char[]	(abc)	ByVal String
C	8	unsigned char	(U8)	ByVal Byte
PC	32	unsigned char *	(U8) by address	ByRef Byte
B	8	char for boolean result 1 = true, 0 = false	(U8)	ByVal Byte
PB	32	pointer on boolean	(U8) by address	ByRef Byte
F	32	float	(SGL)	ByVal Single
PF	32	pointer on float	(SGL) by address	ByRef Single

NB:

1) in Visual Basic, all values are signed

2) After calling mfcs_initialisation, a delay (0.5s) must be set before calling other functions,

3) A mfcs_close must be called before leaving the application, to avoid a Windows error.

VBA Declarations Examples

```
Public Declare Function mfcs_initialisation Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal i As Integer) As Long
Public Declare Function mfcs_close Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long) As Byte
Public Declare Function mfcs_read Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal S As String) As Byte
Public Declare Function mfcs_write Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal S As String) As Byte
Public Declare Function mfcs_set_purge_on Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long) As Byte
Public Declare Function mfcs_set_purge_off Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long) As Byte
Public Declare Function mfcs_get_purge Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByRef C As Byte) As Byte
Public Declare Function mfcs_get_status Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByRef C As Byte) As Byte
Public Declare Function mfcs_read_chan Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByRef P As Single,
      ByRef Chrono As Integer) As Byte
Public Declare Function mfcs_data_chan Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByRef Su As Byte,
      ByRef Sm As Integer, ByRef Zr As Integer, ByRef Ms As Integer,
```

```
    ByRef Chrono As Integer) As Byte
Public Declare Function mfcs_get_serial Lib "d:\mfcs\mfcs_vb.dll"
    (ByVal H As Long, ByRef Serial As Integer) As Byte
Public Declare Function mfcs_set_auto Lib "d:\mfcs\mfcs_vb.dll"
    (ByVal H As Long, ByVal Chan As Byte, ByVal P As Single) As Byte
Public Declare Function mfcs_set_alpha Lib "d:\mfcs\mfcs_vb.dll"
    (ByVal H As Long, ByVal Chan As Byte, ByVal Alpha As Byte) As Byte
Public Declare Function mfcs_set_manual Lib "d:\mfcs\mfcs_vb.dll"
    (ByVal H As Long, ByVal Chan As Byte, ByVal Ev As Single) As Byte
Public Declare Function mfcs_set_zero Lib "d:\mfcs\mfcs_vb.dll"
    (ByVal H As Long, ByVal Chan As Byte, ByVal Zero As Integer) As Byte
```

About Output Pressurization

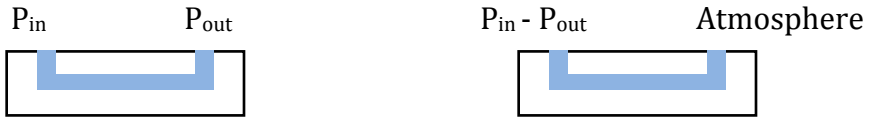


Fig. 51—Pressure must be properly equalized.

In order to operate in an optimized range of the pressure full scale, it is recommended to work with differential pressure. Indeed, by pressurizing both input and output of a channel properly, the pressure inside the channel would be equal to the differential of the output and the input pressures.

MAINTENANCE

The MFCS is designed as a very robust device for usage in laboratory and industrial environment, so it is easy to maintain. Calibrate it regularly (typically every month) or after the MFCS has been displaced, in order to maintain optimal accuracy of the results and compensate for offset drift of the pressure sensors.

The housing can be cleaned with a soft tissue moistened with iso-propanol or window-cleaning products.

Avoid aggressive organic solvents as acetone or chloroform or abrasive cleaning products.

ACCESSORIES

Designation	Reference and Supplier
USB Cable	
CD Software	
User manual	
Blue tubing (OD=1/32'', ID=250µm)	Upchurch Scientific : 1581
FEP tubing (OD=1/16'', ID=800µm)	Fisher : A28556
Glass capillary (OD=360µm', ID=100µm)	Polymicro technologies : TPS100375
Green Sleeves (1/16" to 360µm)	Upchurch Scientific : F-242X
Green Sleeves (1/16" to 1/32")	Upchurch Scientific : F-247X
10-32 Peek Fitting Nuts	Upchurch Scientific : F-120
soft tubing (1x3mm)	Fisher : A31309
Micrew reservoir 1.5 mL	Fisher : W14432

SPECIFICATIONS

MFCS 25 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	500	600	mbar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	23	-	µbar	
Max. output pressure	-	25	-	mbar	
Operation temperature range	5	25	40	°C	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

MFCS 70 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	500	600	mbar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	63	-	µbar	
Max. output pressure	-	69	-	mbar	
Operation temperature range	5	25	40	°C	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

MFCS 350 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	800	900	mbar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	0.32	-	mbar	
Max. output pressure	-	343	-	mbar	
Operation temperature range	5	25	40	°C	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

MFCS 1000 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	1.3	1.4	bar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	0.95	-	mbar	
Max. output pressure	-	1033	-	mbar	
Operation temperature range	5	25	40	°C	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

APPENDIX A

Response and Stabilization Time

Here are the graphic definitions of response time and stabilization time.

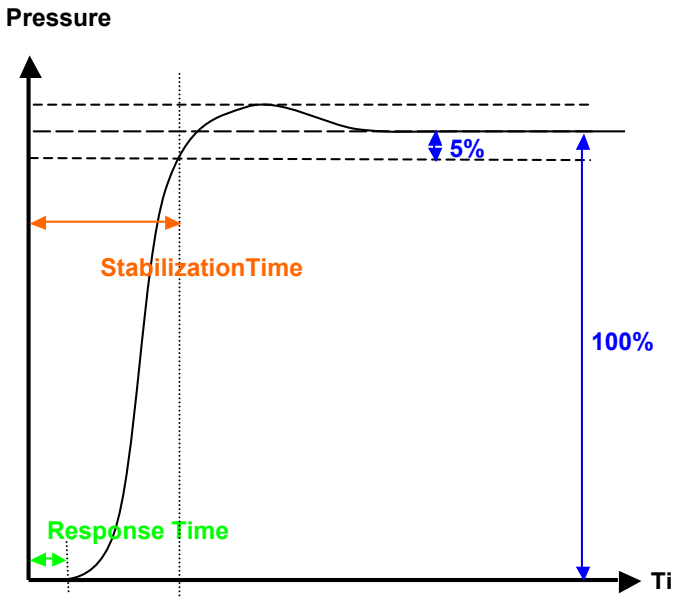


Fig. 52—On this graph you can see when the system begins to respond and when it actually stabilizes.

Unit Conversion Table

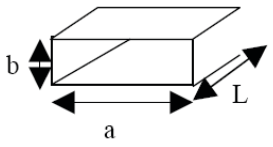
value (↓) = factor xunit (→)	kPa	bar	psi	inch H2O
1 kPa	1	0.01	0.145	4.016
1 bar	100	1	14.5	401.6
1 psi	6.895	68.95x10-3	1	27.68
1 inch H_2O	0.249	2.49x10-3	3.612x10-2	1

Example: 10 kPa = 10 kPa x 0.01 bar/kPa = 0.1 bar

Hydrodynamic Resistance of Rectangular Channels and Networks

Pressure difference (Δp), the volume flow rate (Q), or the averaged velocity (u) and the friction coefficient (C) are related with channel dimensions (a and b) when a/b>>1, channel length (L) and viscosity (μ). (μ= 9.5 x10^{-4} Pa s for H_2O at 25°C)

$$Q = C\frac{ab^3}{L\mu}\Delta p = abu$$



The relation between the friction C and the aspect ratio a/b can be calculated [Stone, Stroock, Ajdari, Ann. Rev. Fluid. Mech., 2004]:

$$C = \frac{1}{2}\xi^2 \sum_{n=1}^{\infty} \frac{1}{\beta_n^4}\left[1 - \frac{1}{\beta_n}\tanh(\beta_n \xi)\right],$$

with

$$\beta_n = \frac{(2n-1)}{2}\pi, \xi = \frac{a}{b}$$

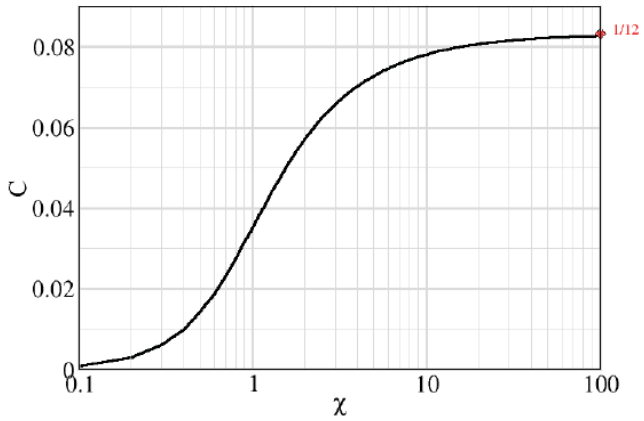


Fig. 53—This graph shows the friction coefficient as a function of the aspect ratio of the channel and can be used to estimate the flow rate due to a given pressure difference. Typical values are: x=1 ⇒ C=0.03512; x=2 ⇒ C=0.05708; x=10 ⇒ C=0.07688.

Example: A channel of 10x100μm with a length of 10mm contains 0.01μl. Applying a pressure difference of 10Pa (=100 μBar) gives a volume flow rate of about Q=0.0005μl/

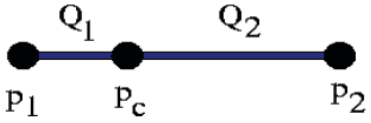
min and an averaged flow velocity of u = 5µm/min. A pressure of 100,000 Pa (=1 bar) is 10,000 times higher, thus the flow rate and velocity are also 10,000 times increased.

Since Ohm's law also applies to flow of other particles than electrons (for example, water), we can transfer the formulas.

For a single channel, we have for the volume flow (Q) as a function of the externally applied pressure difference (p) and the resistance (R): Q=p /R, Q=abu.

The pressure (pc) at an arbitrary position in a single channel with partial resistances (R1 and R2) of the two halves of the channel is:

$$p_c = \frac{(p_1 R_2 + p_2 R_1)}{(R_1 + R_2)}$$

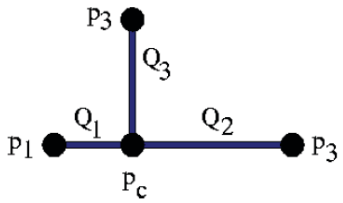


The total resistance is R=R1+R2, the flow yields Q=(p1−pc)/R1, R2 is equivalent.

If the two parts are of equal resistance (equal length and diameter), we find the well known average value: pc=(p1+p2)/2

For three channels (p1, p2, p3 and R1, R2, R3) joining in one point with pressure (pc) we find using the continuity equation (the sum over all Qs going into one knot vanishes)

$$p_c = \left[\frac{p_1}{R_1} + \frac{p_2}{R_2} + \frac{p_3}{R_3}\right] \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3}$$



The corresponding flow in channel 1 (as an example) can be obtained with Ohm's law:

Q1=(p1−pc)/R1

The other values are equivalent.

To obtain the corresponding formulas for n channels joining in one knot, the latter formula can be generalized:

$$p_c = \frac{\sum_i^n \frac{p_i}{R_i}}{\sum_i^n R_i^{-1}}$$

More complex geometries can be calculated using well-known methods in analogy to electrical resistor networks (pressure is equivalent to the electric potential, flow is equivalent to the current, and flow resistance of a channel plays the same role as the Ohm's resistance).

Trace and Log FIle Formats

MFCScontrol allows a complete real time recording of all settings and measured pressure values during operation.

```
11.07.2005 17:39:03 MFCS S/N:0003 V:000.011
15885   18.424    0.426    5.146   20.560
15886   18.424    0.426    5.100   20.477
15887   18.386    0.395    5.100   20.454
15888   18.371    0.426    5.123   20.583
15889   18.485    0.395    5.100   20.583
15890   18.462    0.426    5.100   20.500
15891   18.402    0.426    5.146   20.500
15892   18.333    0.395    5.123   ...
```

Fig. 54—Example of a trace file

The trace file format consists of a header line and a data block. The header line is composed of the starting date and time, serial number of the connected unit and version number of the MFCScontrol software. The data block is composed of lines carrying a time stamp (absolute time and the internal step number) and the 4 (8) pressure values. '#N/A' means information was lost (for example, transient transmission failure). When using this option, avoid the creation of oversized data files. Adjust the storage frequency, as necessary. (See the pull down menus.)

```
11.07.2005 17:27:38 --BEGIN OF LOG--
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2196
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2221
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2246
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2283
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2332
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2381
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2406
11.07.2005 17:27:45 AUTO.      Chan. 1 :  2715
11.07.2005 17:27:45 AUTO.      Chan. 1 :  2727
11.07.2005 17:27:46 AUTO.      Chan. 1 :  2739
11.07.2005 17:27:46 AUTO.      Chan. 1 :  2739
11.07.2005 17:27:46 AUTO.      Chan. 1 :  2739
11.07.2005 17:39:27 --END OF LOG--
```

Fig. 55—Example of a Log file

Command	Order
ALPHA Chan. X : YYYYY	set value to YYYYY in Channel X
AUTO Chan. X :YYYYY	set value YYYYY in Channel X in feed back mode
--BEGIN OF LOG--	start logging
--END OF LOG--	stop logging

Command	Order
MANUAL Chan. X : YYYYY	set value YYYYY in Channel X in manual mode
PURGE OFF	open purge valve
PURGE ON	close purge valve
USB OFF	close USB channel
USB ON	open USB channel
ZERO Chan. X : YYYYY	set zero value YYYYY on channel X

Fig. 56—Commands sent from the computer to the MFCS

Order	Message
mfcs exceeding input pressure	input pressure exceeds threshold value
mfcs operating	system is operating normally
mfcs purge off	purge is switched off
MFCS S/N:---- V:----	comprising serial and version number
mfcs purge on	purge is switched on
mfcs reset detected	system has realized activation of reset signal (button, processor reset line)

Fig. 57—Commands sent from the MFCS to the computer.

WARRANTY

WPI (World Precision Instruments, Inc.) warrants to the original purchaser that this equipment, including its components and parts, shall be free from defects in material and workmanship for a period of one year* from the date of receipt. WPI's obligation under this warranty shall be limited to repair or replacement, at WPI's option, of the equipment or defective components or parts upon receipt thereof f.o.b. WPI, Sarasota, Florida U.S.A. Return of a repaired instrument shall be f.o.b. Sarasota.

The above warranty is contingent upon normal usage and does not cover products which have been modified without WPI's approval or which have been subjected to unusual physical or electrical stress or on which the original identification marks have been removed or altered. The above warranty will not apply if adjustment, repair or parts replacement is required because of accident, neglect, misuse, failure of electric power, air conditioning, humidity control, or causes other than normal and ordinary usage.

To the extent that any of its equipment is furnished by a manufacturer other than WPI, the foregoing warranty shall be applicable only to the extent of the warranty furnished by such other manufacturer. This warranty will not apply to appearance terms, such as knobs, handles, dials or the like.

WPI makes no warranty of any kind, express or implied or statutory, including without limitation any warranties of merchantability and/or fitness for a particular purpose. WPI shall not be liable for any damages, whether direct, indirect, special or consequential arising from a failure of this product to operate in the manner desired by the user. WPI shall not be liable for any damage to data or property that may be caused directly or indirectly by use of this product.

Claims and Returns

• Inspect all shipments upon receipt. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed loss or damage should be reported at once to the carrier and an inspection requested. All claims for shortage or damage must be made within 10 days after receipt of shipment. Claims for lost shipments must be made within 30 days of invoice or other notification of shipment. Please save damaged or pilfered cartons until claim settles. In some instances, photographic documentation may be required. Some items are time sensitive; WPI assumes no extended warranty or any liability for use beyond the date specified on the container.

• WPI cannot be held responsible for items damaged in shipment en route to us. Please enclose merchandise in its original shipping container to avoid damage from handling. We recommend that you insure merchandise when shipping. The customer is responsible for paying shipping expenses including adequate insurance on all items returned.

• Do not return any goods to WPI without obtaining prior approval and instructions (RMA#) from our returns department. Goods returned unauthorized or by collect freight may be refused. The RMA# must be clearly displayed on the outside of the box, or the package will not be accepted. Please contact the RMA department for a request form.

• Goods returned for repair must be reasonably clean and free of hazardous materials.

• A handling fee is charged for goods returned for exchange or credit. This fee may add up to 25% of the sale price depending on the condition of the item. Goods ordered in error are also subject to the handling fee.

• Equipment which was built as a special order cannot be returned.

• Always refer to the RMA# when contacting WPI to obtain a status of your returned item.

• For any other issues regarding a claim or return, please contact the RMA department

Warning: This equipment is not designed or intended for use on humans.

* Electrodes, batteries and other consumable parts are warranted for 30 days only from the date on which the customer receives these items.

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